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## Radio Galaxy Spectra

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**Abstract.** Radio spectra of radio galaxies are often ascribed a simple power law form ( $S_\nu \propto \nu^\alpha$ ) with the spectral index,  $\alpha$ , being of order  $-0.7$ . However, all radio galaxies deviate from this simple power law behaviour. In this paper we derive simple expressions for the average rest-frame spectra of FRI and FRII radio galaxies. These will be used to describe the spectral curvature of the parent (FRI and FRII) populations in models of radio source evolution.

The deviation of radio galaxy spectra from simple power law behaviour occurs at two levels: (i) the rest-frame spectral index at low frequency ( $< 750$  MHz) depends on the luminosity of the source – the  $P - \alpha$  correlation (Blundell, Rawlings & Willott 1999) and (ii) the highest-power sources exhibit the strongest spectral curvature at high radio frequencies ( $> 1$  GHz) (Laing & Peacock 1980). In order to pursue models of radio-source evolution, we wish to find simple expressions for the average rest-frame spectrum as a function of radio power and Fanaroff Riley type (Fanaroff & Riley 1974) over a wide radio frequency range.

The 3CRR sample provides a complete set of radio galaxies at  $S_{178 \text{ MHz}} \geq 10.9$  Jy (Laing, Riley & Longair 1983). We have collected flux-density data for 21 FRI and 61 FRII 3CRR radio galaxies from measurements made between 10 and 14.9 GHz. Of the FRIIs, we selected the narrow-line radio galaxies only, to avoid any effects due to orientation. In addition we selected only sources at  $z < 0.3$  to avoid incorporating spectral index – age effects. We scaled the individual survey flux density measurements according to the factors given in Laing & Peacock (1980).

Typical examples of the spectra of our selected radio galaxies are shown in Figure 2. It can be seen that some are close to having  $\alpha = -0.7$  over the frequency range shown (*i.e.* 3C 330), others are flatter than  $-0.7$ , particularly at  $< 1$  GHz (*i.e.* 3C 295), while still others steepen above  $\sim 1$  GHz (*i.e.* 3C 79 and 3C 457).

Because our evolution analysis (Jackson & Wall 1999) uses radio-source counts and luminosity-function estimates derived from data at 151 MHz and 178 MHz, we considered only data at  $\geq 178$  MHz (rest-frame) when deriving the best-fit for each galaxy. We then fitted the data on a radio-power range and

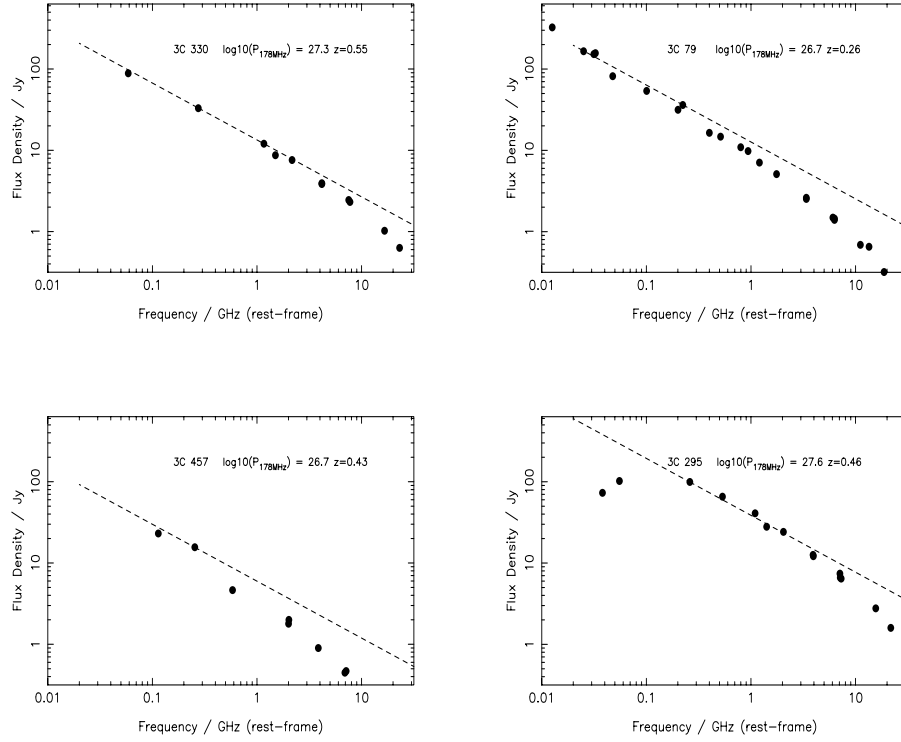


Figure 1. Example spectra for 4 FR II radio galaxies. Observed data points ( $\bullet$ ). Dashed line indicates slope of  $\alpha = -0.7$

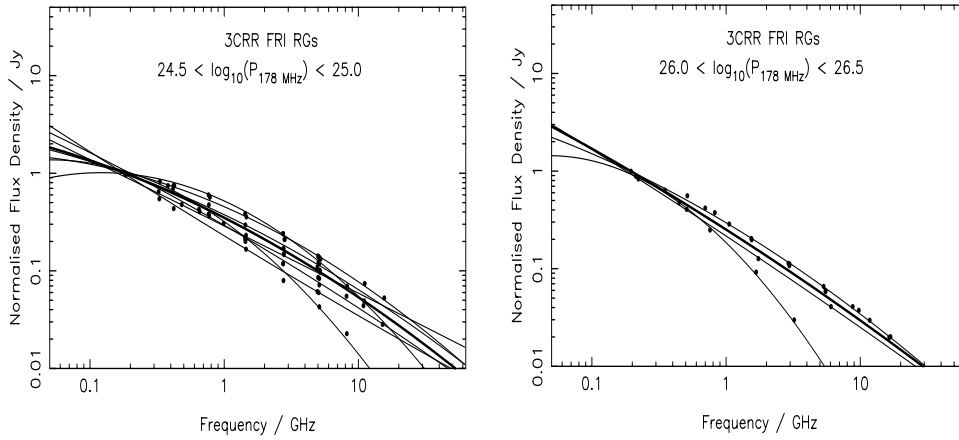


Figure 2. Fitted spectra for individual FRIs (light lines) with radio powers in the ranges show. The data are ( $\bullet$ ) normalised to  $S_{178\text{MHz}} = 1$  Jy. The mean spectrum is the best-fit for  $\nu_{\text{rest}} \geq 178$  MHz (heavy line).

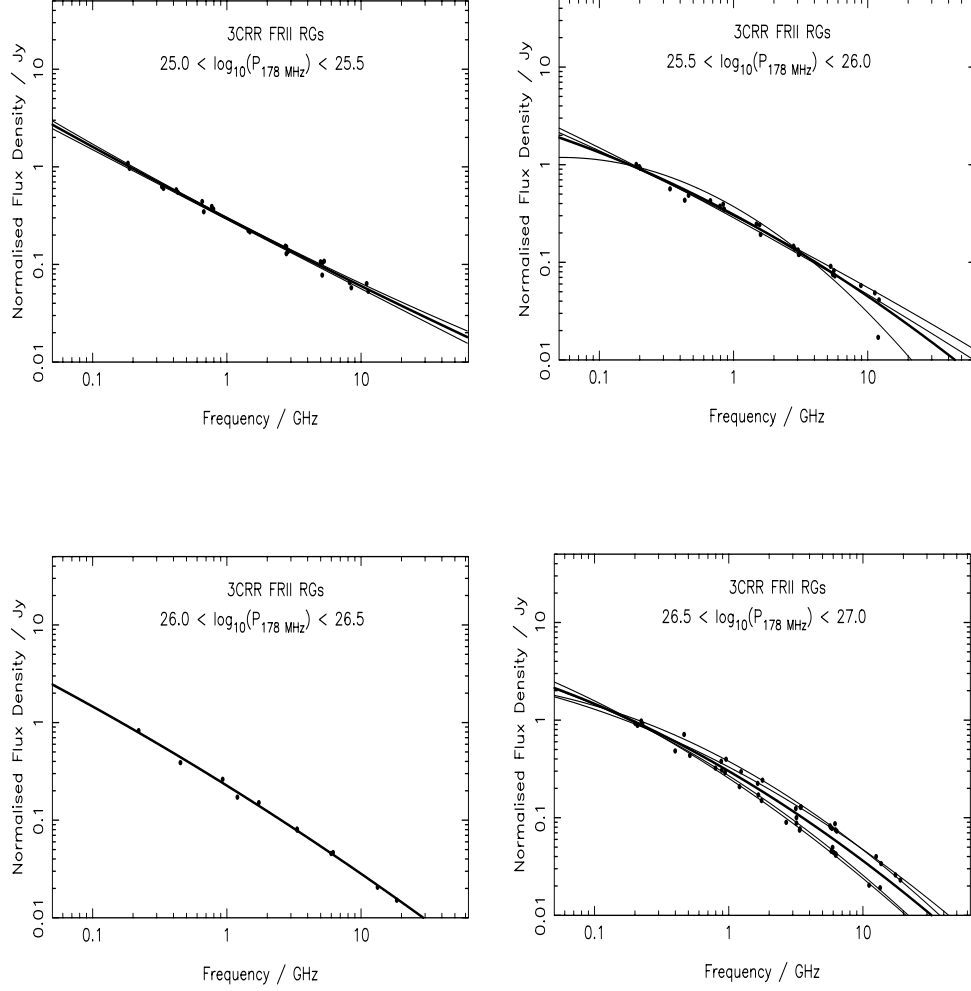


Figure 3. Fitted rest-frame spectra for individual FRIIs (light lines) with radio powers in the ranges show. The data are ( $\bullet$ ) normalised to  $S_{178 \text{ MHz}} = 1 \text{ Jy}$ . The mean spectrum is the best-fit for  $\nu_{rest} \geq 178 \text{ MHz}$  (heavy line).

FR-type basis, as shown in Figures 2 and 3. We fitted a quadratic; and found (Table 1) increasing spectral curvature with increasing P (Laing & Peacock 1980).

Table 1. Spectral fits by FR-type and radio power

Class	$\log_{10}(P_{178 \text{ MHz}})$	Number of galaxies	A	Quadratic terms	
				$B(\log_{10} \nu)$	$C(\log_{10} \nu)^2$
FRI	$24.0 \leq P < 24.5$	5	-0.4626	-0.6424	-0.0692
	$24.5 \leq P < 25.0$	7	-0.4563	-0.7009	-0.1132
	$25.0 \leq P < 25.5$	2	-0.6493	-0.9213	-0.0507
	$25.5 \leq P < 26.0$	4	-0.5582	-0.8286	-0.0279
	$26.0 \leq P < 26.5$	3	-0.5992	-0.8794	-0.0515
FRII	$25.0 \leq P < 25.5$	2	-0.5269	-0.7128	-0.0188
	$25.5 \leq P < 26.0$	3	-0.5114	-0.7372	-0.0982
	$26.0 \leq P < 26.5$	1	-0.6459	-0.8567	-0.0465
	$26.5 \leq P < 27.0$	4	-0.5228	-0.8037	-0.1145

Table 2. Spectral fits by FR-type and radio power

Class	$\log_{10}(P_{178 \text{ MHz}})$	Number of galaxies	Quadratic terms	
			$B(\log_{10} \nu)$	$C(\log_{10} \nu)^2$
FRI	$24.0 \leq P < 25.0$	12	-0.6753	-0.0901
	$25.5 \leq P < 26.5$	7	-0.8484	-0.0395
FRII	$25.0 \leq P < 26.0$	5	-0.7249	-0.0456
	$26.0 \leq P < 27.0$	5	-0.8136	-0.1005

We will adopt the fitted spectra of Table 2 in subsequent modelling of radio source evolution. This will account for the spectral curvature of the FRI and FRII (parent) radio source populations.

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